Stratified Coastal Trapped Waves and Mean Flows

PI:
Daniel R. Ohlsen
Program in Atmospheric and Oceanic Sciences
Campus Box 311
University of Colorado
Boulder, CO 80309-0311
phone: 303-492-8237 fax: 303-492-3524 email: Daniel.Ohlsen@colorado.edu

Co-I:
LuAnne Thompson
School of Oceanography
Box 357940
University of Washington
Seattle, WA 98195
phone: 206-543-9965 fax: 206-685-3354 email: luanne@ocean.washington.edu

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LONG-TERM GOALS

Our long term goals are to identify the roles that rectified subinertial waves and mesoscale motions play in the mean-flow transport of fluid properties in the coastal ocean and to apply these ideas to cross-margin transport of physical, chemical, and biological properties.

OBJECTIVES

Coastal waves and wave-generated mean flows are studied in a stratified, rotating model ocean. Waves trapped to the coast are generated by time-dependent flow over a sloping and irregular bottom. Short-term goals of this study include quantifying the evolution of the vertical structure of the along-slope mean flow driven by non-linear interactions of the coastal trapped wave and damped by friction. In particular, the effects of stratification on the cross-slope overturning circulation will be examined.

APPROACH

The approach for this research is to use laboratory experiments and two types of numerical models. The laboratory experiments are fully non-linear by their very nature, while the numerical models provide a useful venue for studying specific processes and offer much better diagnostics.

In the lab experiments, a bowl-shaped tank with radial ridges provides the coastal slope and cross-slope topography to generate wave motions. The entire apparatus rotates and flow over the topography is achieved with a slight spin-up or -down of the rotation rate.

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The water in the bowl is stratified with salt to give a vertical density gradient. Waves are generated by the topography and trapped to the coast by the planetary rotation. The fluid motions are observed by tracking the paths of neutrally-buoyant particles at multiple vertical levels. The initial and evolving stratification is measured with a micro-CTD probe.

Two numerical models are used. One is the coastally trapped wave model developed by Ken Brink and Dave Chapman at WHOI for the study of the linear response, and a fully non-linear isopycnal numerical model is being used to directly simulate the laboratory experiment with laboratory geometry and parameters.

WORK COMPLETED

The numerical results are discussed in the annual report by Thompson. The following laboratory modeling work has been completed:

1. Careful measurements of the laboratory experimental geometry were done to use as inputs for the numerical model.

2. Experiments at a number of stratifications, rotation rates and two topographic amplitudes have been carried out for both spin-up and spin-down forcing. Comparisons to the isopycnal numerical model results have been done.

RESULTS

Comparisons between the laboratory experiments and numerical model (Figures 1 and 2, compared to Thompson annual report Figures 1 and 2) suggest that the qualitative evolution of the mean flow (average azimuthal velocity) and the flow structures are independent of the form of the frictional parameterization, but the time-scale over which the azimuthal velocity slows does depend strongly on friction (Figure 2). This suggests that wave-mean flow interaction for coastally trapped waves is relatively independent of the frictional parameterization in its structure, although the magnitude of the effects on the mean-flow do depend on friction.

With finite amplitude topography, mean flow modification occurs near the topography in each layer. The qualitative agreement between the numerical and laboratory models over a range of rotations, stratifications and topographic amplitudes lend credence to the numerical mass flux calculations.

IMPACTS/APPLICATIONS

We expect to gain a new understanding of one possible forcing mechanism of cross-margin transport and extend our results to wind-forced wave motions on the continental shelf. The difference between the spin-up and spin-down cases suggest that there will be large differences in the cross-slope transport for northward or southward mean flows on the coast. The qualitative similarity of the motions in the laboratory and numerical models suggests that friction parameterization is not critical to applications of these ideas to the coastal ocean.

TRANSITIONS

RELATED PROJECTS

REFERENCES

Ohlsen, D.R. and L. Thompson, 1997: Laboratory study of stratified coastal waves and mean flow, AMS Atmosphere and Ocean Waves and Stability Conference abstract, Tacoma, WA, June, 1997.

Thompson, L., D. Darr, and D.R. Ohlsen, 1997: Stratified coastal trapped waves and mean flows, AMS Atmosphere and Ocean Waves and Stability Conference abstract, Tacoma, WA, June, 1997.

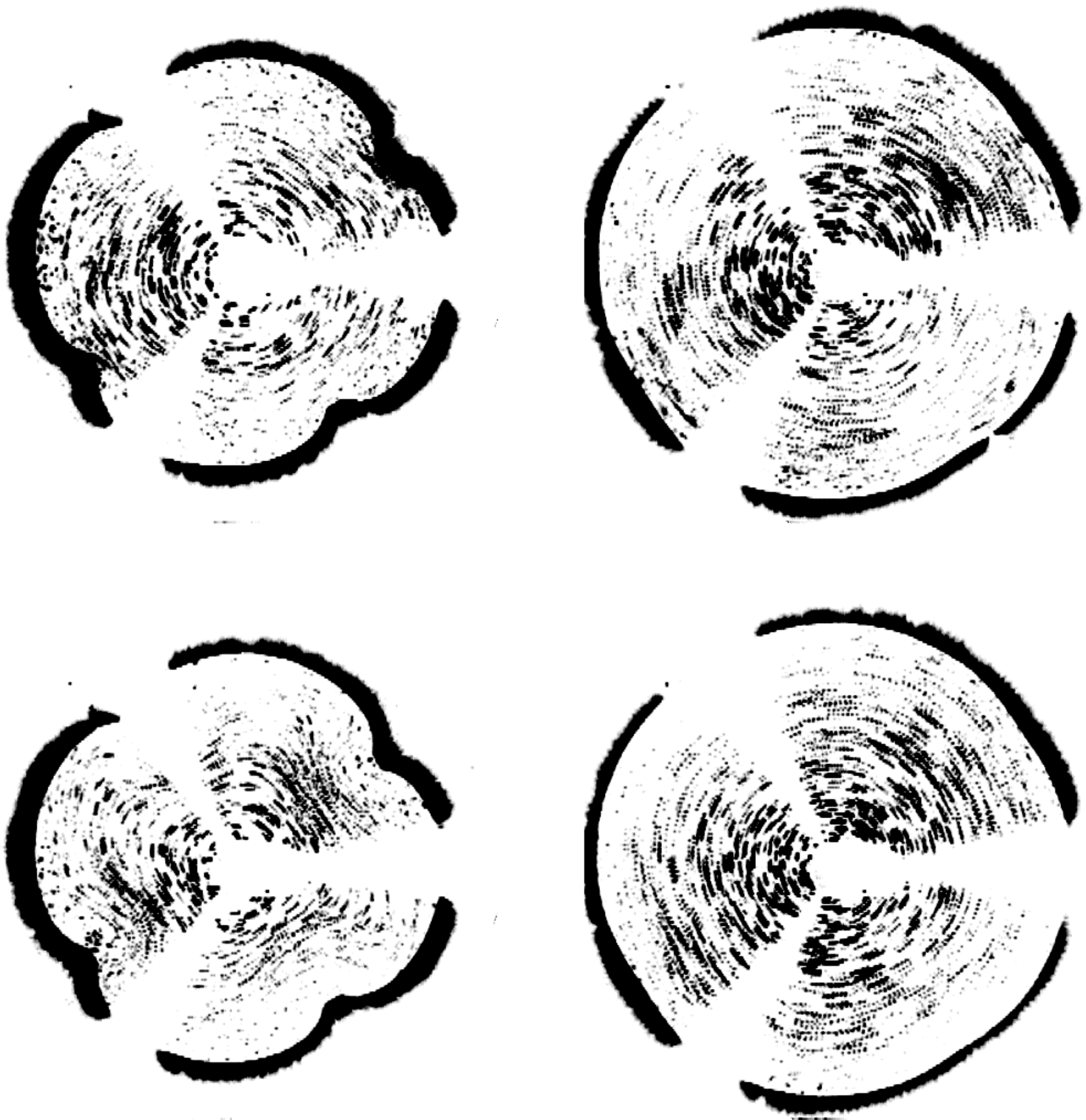

Figure 1. Multiple exposure “streak” images for laboratory experiment with same parameters as in Thompson report, Figure 1, but after 300 seconds. The right (left) panels are about 1/3 from the bowl bottom (top) for cyclonic (upper panels) and anticyclonic (lower panels) forcing.

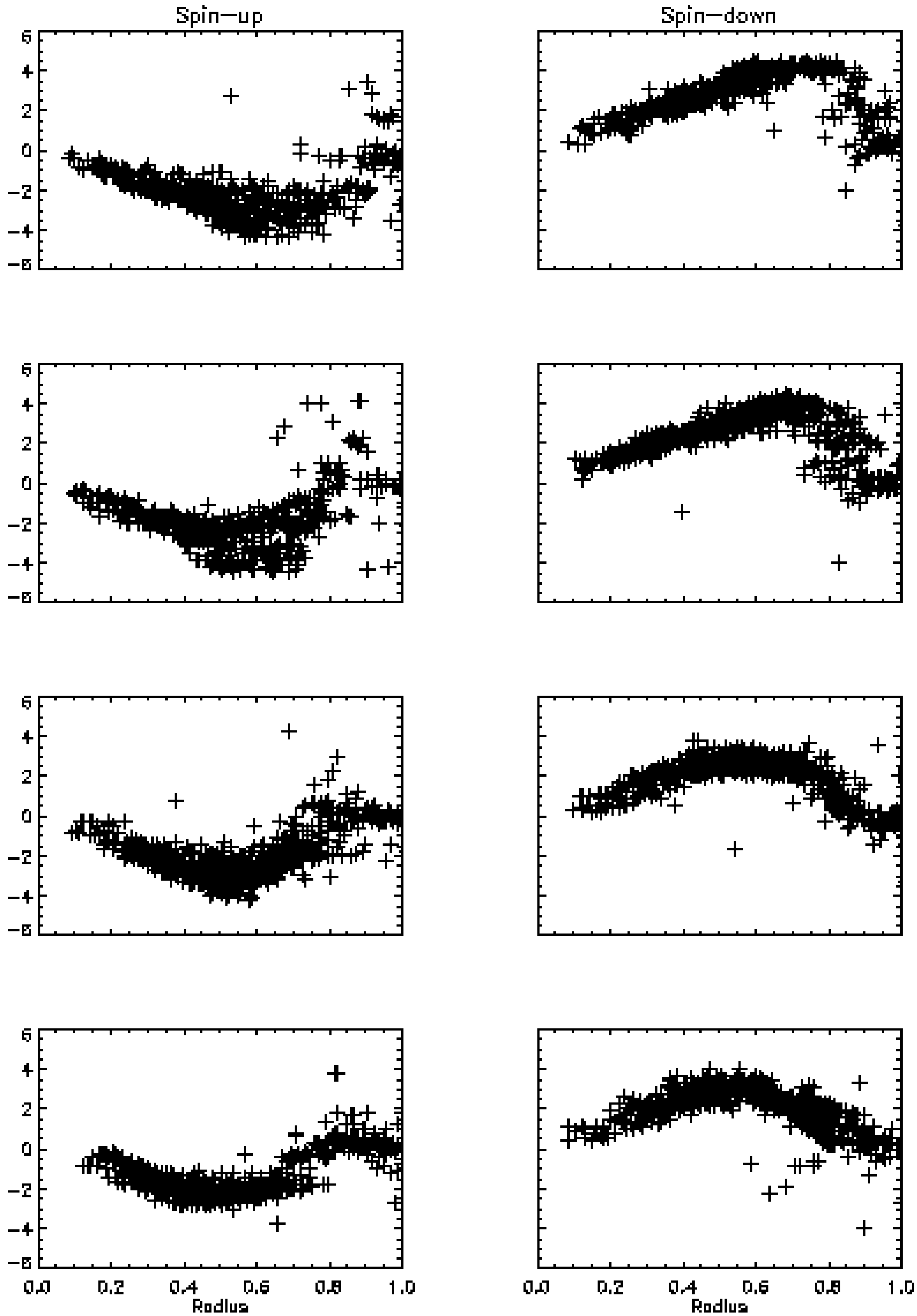

Figure 2. Azimuthal particle velocities as a function of radius for the same experiment as Figure 1. The right (left) column shows anticyclonic (cyclonic) velocities after 60, 120, 300, and 600 sec. Note the similarities to Thompson report, Figure 2 but with slower time evolution than in the numerical model.